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U. S. Coast Guard Fleet Mix Planning:
A Decision Support System Prototype

by

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and
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The objective of this thesis is to analyze the fleet mix planning problem, develop an approach to evaluate alternative fleet mixes, and implement the approach in a decision support system (DSS). In particular, this research is conducted in the context of the acquisition of a mix of patrol boats to replace the aging Point Class patrol boats within the U. S. Coast Guard. The analysis of an alternative fleet mix involves, among other things, the evaluation of cost, activity and performance measures for that fleet mix. Several analytic and forecasting models are used to determine costs and activity measures for various fleet mixes, and simulation games are played to assess expected mission performance for each mix under a set of mission scenarios. A rule-based deductive model is employed to determine and score the response of a given fleet mix to events occurring during the simulation. These models are implemented and integrated in a decision support system which combines the mathematical models with a database system, an expert system, and user interface tools. It is hoped that repeated use of the system, analysis of the alternative fleet mixes using a large number of data sets, and post-evaluation analysis and explanations, will help provide the decision-maker insight in to the problem, and will facilitate a judicious decision.

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ABSTRACT

The objective of this thesis is to analyze the fleet mix planning problem, develop an approach to evaluate alternative fleet mixes, and implement the approach in a decision support system (DSS). In particular, this research is conducted in the context of the acquisition of a mix of patrol boats to replace the aging Point Class patrol boats within the U. S. Coast Guard. The analysis of an alternative fleet mix involves, among other things, the evaluation of cost, activity and performance measures for that fleet mix. Several analytic and forecasting models are used to determine costs and activity measures for various fleet mixes, and simulation games are played to assess expected mission performance for each mix under a set of mission scenarios. A rule-based deductive model is employed to determine and score the response of a given fleet mix to events occurring during the simulation. These models are implemented and integrated in a decision support system which combines the mathematical models with a database system, an expert system, and user interface tools. It is hoped that repeated use of the system, analysis of the alternative fleet mixes using a large number of data sets, and post-evaluation analysis and explanations, will help provide the decision-maker insight in to the problem, and will facilitate a judicious decision.

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To our wives:

Mary Cortez and Carol Kaiser

for their unfailing love

throughout this endeavor

I. INTRODUCTION

This research examines and analyzes the fleet mix planning problem, develops a simulation approach to evaluate the performance of alternative fleet mixes, and implements this method in a decision support system (DSS). Further, we present and apply our solution approach for fleet mix planning in the context of patrol boat acquisition within the United States Coast Guard (USCG). The DSS presents evaluation results for alternative fleet mixes, allowing a decision maker the ability to make comparisons and decisions. The system is being used by the USCG which provided us with an ideal application within the Patrol Boat Capability Replacement Project office.

A. BACKGROUND

Fleet mix planning is an important issue within many organizations including rental vehicle companies, the U.S. Navy and the U. S. Coast Guard. This section provides an overview of the fleet mix problem with specific references to the Coast Guard patrol boat fleet mix.

1. Fleet Mix

Broadly defined, a fleet mix is a combination of various assets. Within our scope a fleet mix is defined as a combination of various vessels, assigned to specific homeports, that have been selected to maximize performance or minimize costs while meeting the requirements of the assigned mission. An example of a fleet mix is a nationwide car rental agency. The agency operates in an industry where having the right mix of cars is crucial to competing with other agencies. The similarities between a car rental agency and the Coast

Guard are limited, but worth a brief comparison. Both are required to provide the proper mix of assets to their selected locations. Both also schedule maintenance periods for assets while still meeting their mission objectives. In addition, both must have rapid availability on short notice.

2. Patrol Boat Fleet Mix

The Coast Guard has traditionally called its vessels *cutters* and distinguished those that are 80 to 120 feet in length by referring to them as patrol boat cutters [Ref. 1:p. 14]. The Coast Guard currently has approximately 100 patrol boats that operate in eight coastal districts throughout the United States, including Hawaii and Alaska. The patrol boat fleet consists mainly of boats in two classes: the Point class and the Island class. The primary mission requirements of the patrol boat fleet are enforcement of law and treaties[1] (ELT), search and rescue (SAR), and defense operations [Ref. 1:p. 14]. Secondary missions are marine environmental protection (MEP), marine safety and aids to navigation.

3. Replacing the Point Class Patrol Boat

The Point Class patrol boats are approaching the end of their useful service life. The Coast Guard is planning to retire the aging Point class patrol boats gradually during the decade of the 1990's [Ref. 2:p. 1-1]. The Patrol Boat Capability Replacement Project office is studying candidate replacement cutters that can fulfill mission requirements and have better performance than its predecessor.

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[1]Drug interdiction is a highly visible mission and a part of ELT.

4. Candidate Replacement Cutters

There are three candidate replacement cutters being considered by the Patrol Boat Capability Replacement Project office. The first is the Island class patrol boat that has a length of 110 feet. This patrol boat class has been in service since 1983 and is still being built for the Coast Guard. The Coast Guard plans to acquire 47 of these patrol boats. The second candidate is the Heritage class patrol boat that has a length of 120 feet. This cutter was designed by the Coast Guard Naval Engineering division for improved stability and endurance over previously designed patrol boats [Ref. 2: p. 2-14]. The prototype ship is expected to be completed in 1992. The third candidate replacement cutter is the notional design patrol boat. Initial design studies are still in progress. Preliminary design objectives for the vessel include a shallow draft with a length of 75 to 85 ft.

5. Reasons for a Mixed fleet

Each candidate replacement class has certain advantages and disadvantages when compared to the other classes [Ref. 2]. For example, the 80 foot Notional design craft would require fewer crew (therefore, lower personnel costs), would be more fuel efficient at a given speed, and would have a shallower draft than either the Heritage or Island class patrol boats. These benefits could be significant if the mission requirement was primarily SAR, where a small, nimble and shallow draft vessel could maneuver near shoal water.

However, the Notional design would have a lesser endurance of three days compared to five or seven days for the other two candidate patrol boats. The vessel would be less stable in heavy seas. With a smaller crew, the

notional design would also have difficulty supplying a four or five member boarding party[2]. These limitations would hinder the Notional patrol boat as a drug interdiction vessel, where endurance and boarding parties are important factors.

Utilizing a mixed patrol boat fleet gives the Coast Guard a higher flexibility in accomplishing its mission objectives. Limiting replacement of the Point class patrol boat to one class of vessels would restrict selection opportunities. The tradeoffs between various kinds of vessels and the need to diversify the fleet are important considerations. A decision to improve the capability of the fleet in one evaluation category will most often result in a tradeoff or degradation in another category. For example, patrol boats could be designed with larger fuel tanks and more bunks for watchstanders, to provide an increased endurance at sea. The tradeoff is that the cost of the vessel would increase, and maximum speed of the patrol boat would likely be reduced for a given engine horsepower. Similarly, a decision to reduce the costs in one category (acquisition cost) will most often require a higher cost in another area (maintenance costs) or may cause degradation in a capability (lower maximum speed).

6. Complexity of Fleet Mix Planning

Many factors must be considered when selecting a fleet mix. A new fleet is not restricted to being uniform with respect to type, size, or configuration of vessel. Figure 1 illustrates the complexity of the replacement

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[2]A boarding party is used to inspect other vessels for compliance with U. S. laws and treaties. A small boat is sent from the patrol boat to the other vessel. Five personnel are normally needed for this operation.

process. The Patrol Boat Capability Replacement Project office must contend with all of these factors. These complex factors are individually presented in Chapter II. Simply stated, the task is to determine a fleet mix for a given time frame, that will fulfill mission requirements, and any new unknown requirements, given that only X number of boats can be built per year, and that the decision is restricted by a congressionally mandated budget. The decision makers must consider the relative advantages and disadvantages of the alternative fleet mixes.

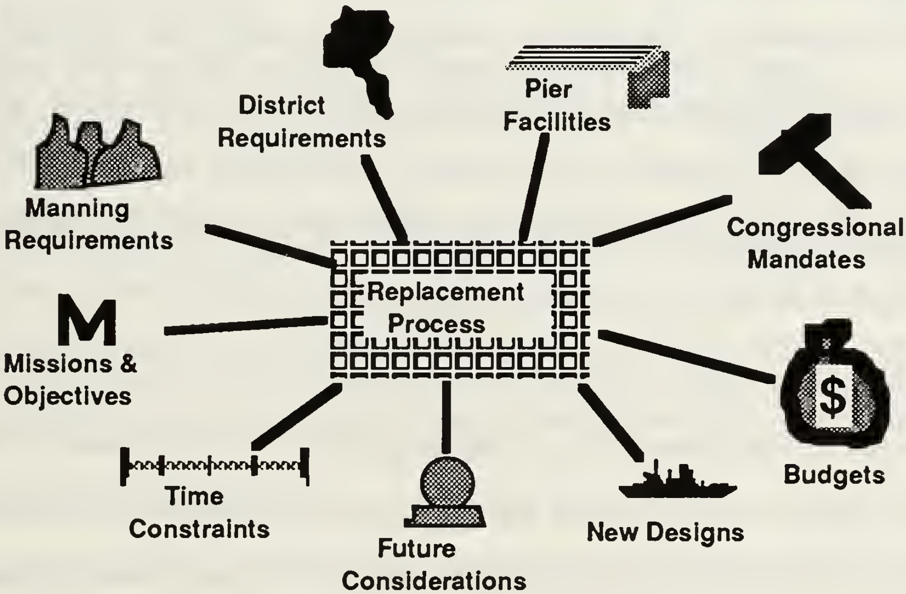

Figure 1-1 Complexity Issues of the Replacement Process.

B. RESEARCH OBJECTIVES

The objectives of this thesis are 1) to propose a method for addressing fleet mix planning, and 2) to design a prototype DSS that will support the specific application in patrol boat acquisition. The four primary research questions that are guiding this thesis are:

- What information should the DSS provide to facilitate judicious fleet mix decision making?
- What information presentation approach should be used to provide the user easy access to concise information?
- What factors, attributes, or characteristics of a fleet mix are relevant in making relative comparisons between alternatives?
- What factors are relevant in justifying the results obtained from a fleet mix alternative?

C. PROPOSED SOLUTION

Our goal has been to develop a prototype DSS that would be immediately useful and would help a decision maker select a better fleet mix alternative. This paper presents an approach to fleet mix planning that 1) assists decision makers in developing and comparing arguments regarding alternative courses of action, 2) presents the attribute measures in an accessible and easy to understand format, and 3) provides a DSS that will be immediately useful to solve part of the fleet mix problem [Ref. 3:p. 11-14].

D. SCOPE

The focus of this research is on the acquisition of patrol boats in the Coast Guard, one aspect of the broader fleet mix planning process. The research will design and develop a prototype DSS that will allow Coast Guard planners to:

- select patrol boats for the fleet mix alternative. Options will include the 82 ft. Point class[3] (WPB 82), the 110 ft. Island class (WPB 110), the 120 ft. Heritage class (WPB 120), and the Notional design patrol boat (WPB 80). The user can modify any characteristics of the above patrol boats. Additional DSS features allow new patrol boat classes to be defined by the user.

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[3]Though the Point class patrol boats will be retired soon, the class is included to provide the baseline fleet mix.

- define or modify homeport assignment of each patrol boat within a fleet mix.
- compose multiple fleet mix alternatives.
- evaluate fleet mix alternatives on the basis of cost, activity, and performance measures.

For demonstration purposes, we will evaluate three fleet mix alternatives proposed by the Coast Guard. The selected fleet mixes are: a fleet mix consisting of the present mix of patrol boats[4], and two hypothetical fleet mix alternatives. The present fleet mix will serve as a baseline for comparison studies.

The research will not:

- evaluate helicopters and other airborne Coast Guard assets.
- evaluate other missions of the USCG (i.e. buoy tending and polar operations)
- provide an absolute value of fleet mix performance. The DSS will provide relative performance measures that can be compared to other fleet mix alternatives.
- rank order fleet mix alternatives. Instead the decision maker compares the evaluation results, assigns his own relative weight to the displayed performance measures, and selects the better fleet mix alternative.

E. THESIS ORGANIZATION

Chapter II discusses the fleet mix planning problem and presents an alternative solution approach to the problem. Chapter III presents the fleet mix DSS design and introduces our functional approach. Chapter IV discuses the implementation of the fleet mix DSS. Fleet Mix analysis is discused in Chapter V. In Chapter VI we summarize the findings and propose ideas for further research.

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[4]The baseline fleet mix uses the patrol boats operating on January 1, 1991.

II. THE FLEET MIX DECISION MODEL

This chapter provides an overview of the fleet mix decision environment as it relates to patrol boat replacement in the U. S. Coast Guard. It also introduces our approach for decision making in this context. The first section describes the fleet mix planning problem. The second section discusses various stages in the fleet mix decision process. The third section discusses alternative approaches for solving fleet mix problems. The last section presents an overview of our solution approach.

A. THE FLEET MIX PLANNING PROBLEM

The patrol boat fleet mix planning problem is complex and has been a major consideration of the Coast Guard's Patrol Boat Capability Replacement Acquisition project. New patrol boats are needed during the 1990's to replace the Point class patrol boats. The following questions are typical of the questions facing the Patrol boat planners. How many patrol boats are needed to meet the mission requirements? What types of patrol boats are most cost effective in the fleet mix? How many of each type should be purchased? Where should the patrol boats be located to best fulfill the mission requirements?

We analyze the fleet mix planning problem by considering the following aspects in this section: uncertainty, objectives and constraints, evaluation criteria, variables, and information requirements.

1. Uncertainty

The planning of a fleet mix is complicated by various kinds of uncertainty. There is uncertainty about the type of activities that will be assigned to patrol

boats in the future [Ref. 3:p. 14]. As stated in Chapter I, the primary mission areas for patrol boats are currently SAR and drug interdiction (ELT). The SAR mission may be assigned to patrol boats, helicopters, fixed wing aircraft or other Coast Guard vessels, depending on the nature of the incident, the location of the incident and assets available for response. The drug interdiction mission is currently assigned to patrol boats, aircraft, aerostats, and other sensors and assets outside the Coast Guard. In the future, the mission emphasis for patrol boats may change. For example the Coast Guard may not be involved in towing vessels to port, but instead would arrange to have disabled vessels towed to port by a private rescue company hired by the boat owner.

There is uncertainty about the future demand for Coast Guard patrol boat response. The demand for a given day is the number of boating accidents or drug activity in the coastal waters that require patrol boat response. The geographic distribution (location) of future activity is also unknown. For example, the information about where incidents will occur, when they will occur and the type of response required by the Coast Guard is difficult to predict, even in terms of probability distributions. Fundamental changes in our society, such as changes in boating patterns, a dramatic rise in fuel prices or elimination of illicit drug use could affect the demand for patrol boats.

2. Patrol Boat Fleet Mix Objectives and Constraints

The Coast Guard patrol boat capability replacement project prepared a Mission Needs Statement in 1983 for the patrol boat replacement study. A partial listing is presented below. The patrol boat replacement "must possess the capability to:

> Perform multi-mission patrols in coastal waters with an endurance of approximately five days.

Intercept, overtake and maintain hot pursuit of waterborne craft normally used for illicit operations.

Provide a five person custody crew to sail a seized vessel up to 24 hours while escorting the vessel and the custody crew.

Carry out all described activities in 10-foot high sea conditions, and be able to operate at a reduced performance level in 25-foot seas and 60 knot winds." [Ref. 4:p. 4]

Constraints on the fleet mix planning problem limit the range of solution possibilities. Following is a brief look at the constraints imposed:

- Budget. Proposed budgets for all aspects of patrol boat acquisition, operations, maintenance and retirement must be approved by Congress.
- Personnel. The number of personnel available to crew patrol boats. A solution that requires more boats than can be operated by the available personnel would be infeasible.
- Geography. The Coast Guard has selected certain ports as patrol boat homeports. Each port has a limited pier size, a limited turning basin (for maneuvering patrol boats near the pier) and limited water depth in the sea access channel. Although new homeports can be developed and access channels can be dredged, the additional expenses incurred must be considered in the process.
- Vessel Capabilities. Once the vessel is designed and built, attempts to improve sea keeping, maximum speed, or attempts to change the vessel draft are difficult and expensive.

3. Measurement Criteria

The fleet mix decision support system will facilitate the comparison of alternative fleet mixes. The relative advantage of one fleet mix alternative over the others is determined by comparing the various measures for each fleet mix. We define three types of measures to evaluate a fleet mix. These are measures of mission performance, potential activity (capability), and costs.

Performance measures indicate how well a fleet might accomplish its mission. The measures include the number of successful missions, the average time required to reach the scene of a SAR case and the number of failed missions.

Activity measures show the portion of time used (or available) for each of the patrol boat's tasks. These measures include patrol hours and maintenance hours. Cost measures capture the cost of using resources by the patrol boats within the fleet mix. Examples include personnel costs for boat crews, operating costs and acquisition cost.

4. Variables

Analysis of a fleet mix involves the study of important variables and problem characteristics. Consultation with the Coast Guard patrol boat replacement project and other Coast Guard experts provided insight on the selection of variables. Additionally, variables were selected if they had an impact on at least one of the measures.

Variables in a decision model are either controllable, uncontrollable or outcome variables [Ref. 5:p. 106]. Those variables that the decision maker has measurable effect on are called controllable variables. The decision maker selects values for these variables. An example is homeport assignment for each patrol boat in the fleet mix. Uncontrollable variables are not under the control of the decision maker. Uncontrollable variables in the fleet mix problem include weather conditions, the number of drug boats attempting to enter a port and the number of SAR cases that will occur. Outcome variables or decision variables are the results of a decision model. The decision model performs an evaluation based on the values of the controllable variables and estimated values for the uncontrollable variables to produce an outcome variable.

5. Data Sources

The quality and availability of data affect the quality and reliability of the analysis. Two categories of historical data are important when analyzing the

fleet mix. One category is the patrol boat operational data. This class includes the percentage of time spent on each mission objective, and each aspect of the costs involved in operating a patrol boat for a year. Operational data has been collected by the Coast Guard to support various decisions in the patrol boat acquisition process. The second category is the environmental data. This class includes data about incidents and illicit operations that occur within the Coast Guard's area of responsibility. The Coast Guard maintains databases to collect, sort and retrieve data about SAR cases and law enforcement cases (which include ELT). Details about unreported accidents and illicit activity are obviously not available.

B. THE FLEET MIX DECISION PROCESS

The fleet mix planning problem encompasses a broad range of decisions from the initial acquisition through disposal of the retired hull. The focus in this research is on the acquisition of patrol boats. The acquisition decision needs to be justified to the Department of Transportation and Congress. Factors outside the Coast Guard may affect the fleet mix selected. These aspects of the fleet mix decision process are discussed below.

1. Decision Lifecycle.

Replacement of patrol boats requires several major steps. The Office of Management and Budget has defined a process that must be followed when acquiring new major systems, including a new class of patrol boats. The A-109 Circular (1977) requires that the responsible office (USCG) establish mission needs and operational requirements for the new system (patrol boats). The first four milestones and three phases of the process are summarized below [Ref. 6:p. 1 - 2].

- Milestone 0: The Coast Guard determines if an identified mission warrants the study of alternative concepts. Identify the minimum set of alternative concepts.
- Phase I: This is the Concept Exploration and Definition Phase where various alternatives are explored for meeting the mission needs, and the most promising concept is identified.
- Milestone I: The Coast Guard determines if the results of Phase I warrant establishing a new acquisition program.
- Phase II: This is the Demonstration and Validation phase. Objectives of this phase include proving the capability of the preferred system by developing a prototype and developing analysis for supporting the Milestone II decision.
- Milestone II: The Coast Guard determines if phase II warrants continuation, and if so, establishes a development baseline containing program cost, schedule and performance objectives and acceptable variances.
- Phase III: The objectives of Phase III are to develop a stable ship design, and demonstrate through testing that the system capabilities can be attained and meet the mission need.
- Milestone III: This is Production Approval. The Coast Guard determines if Phase III warrants continuation and if so, establishes a production baseline.

The fleet mix decision lifecycle also includes decisions about homeport assignment, timing of mid-life maintenance to the patrol boats and retirement of patrol boats. Since acquisition is the current concern of the patrol boat replacement project, this research will focus on the acquisition process.

2. Justification of the Decision.

Each decision in the acquisition process is reviewed based on the justification and supporting evidence provided by the responsible office (patrol boat replacement project). With tight federal budgets, only those programs that are presented as meeting a real need and are cost effective will be approved. Weak justification and lack of supporting evidence for a proposed acquisition would reduce the probability of the acquisition being authorized by Congress.

Therefore to be useful, a decision support system must have features to provide supporting evidence and justification for decisions.

3. Other Factors Affecting the Fleet Mix Decision.

The political nature of the congressional appropriation process is an unknown factor in the fleet mix decision. The decisions regarding patrol boat construction and location of homeports will ultimately be approved, modified or rejected by Congress. Their decisions may not reflect the depth of evidence supporting one alternative over another.

C. ALTERNATIVE SOLUTION APPROACHES

There is no existing integrated set of models that provides analysis for the whole planning problem. At least a small set of models of the Coast Guard's patrol boat operation is necessary to evaluate and compare fleet mix alternatives. One alternative fleet mix approach is presented below.

1. The Balance Sheet Approach

[Ref. 3] states that the fleet mix problem is conceptually an optimization problem with multiple objectives in an uncertain environment. The authors point out practical problems with a single large, complex, multiobjective stochastic model. They used a DSS approach to solving the fleet mix problem [Ref. 3:p. 11]. The DSS was designed to help decision makers in developing and comparing arguments regarding alternative courses of action. In the balance sheet concept, a list of key fleet attributes that can be measured is developed. The list is presented in an accessible, easy-to-explore manner in the DSS. Seven attributes were chosen to represent the comparison of fleets: the annualized cost of a fleet, a performance index, a flexibility index, a fleet quality index, the number of aircraft, the number of major ships and the number of at-sea officer

billets. Three of the attributes need a brief explanation. The performance index is the "value of a multiattribute utility model that accumulates measures of effectiveness values across all major assets in the fleet" [Ref. 3:p. 13]. The fleet quality describes how worn out the fleet is. The flexibility index measures the range of assets available in the fleet.

The DSS was designed for the Coast Guard in the general area of fleet mix planning. The authors indicate that their prototype DSS has met with some initial success.

D. FLEET MIX MODELS

In the past, the Coast Guard has used two models for specific aspects of fleet mix planning. The first predicts the performance of a vessel on patrol. The other model evaluates the performance of vessels in a SAR simulation.

1. Patrol Boat Performance.

"Predicting Patrol Performance" [Ref. 7] presents an approach using a Markov model for predicting the performance of a vessel of patrol. The author presents a classification of the patrol activities of a vessel and a list of characteristics important for modeling patrol boat capabilities.

2. SAR Simulation

The "Search and Rescue Monte Carlo Simulation" [Ref 8:p. 15] uses a simulation approach to measure the effectiveness of various types of proposed patrol boat designs in a SAR situation. The authors include salient aspects of a typical SAR case (distance to datum, search, survival time and weather) in their model.

E. SOLUTION APPROACH

Having defined the problems in fleet mix planning, we present an overview of our approach here and discuss it in more detail in Chapter III. The DSS will assist decision makers in developing and comparing arguments regarding alternative courses of action. The fleet mix alternatives selected by the user are evaluated by the DSS in the attributes of cost, potential activity and performance. Evaluation results for all fleet mix alternatives are presented in a common table, allowing the user to detect advantages and disadvantages of one fleet mix alternative relative to the others.

The performance measures for a fleet mix alternative will be produced using a computer simulation. A computer simulation is used to simulate a real world event or a set of events, under a controlled set of rules, and executes a series of actions that are then measured for comparison [Ref. 5:p. 108]. Specifically, we simulate a fleet of patrol boats, operating within a designated boundary (namely a Coast Guard district), and measure the performance using a set of randomly generated events. For example, one of the randomly generated events is a SAR case. A Coast Guard cutter will need to respond. A cutter will be selected, and set on course to commence search and rescue assistance. Appropriate characteristics of the cutter and the event will be measured. Example of these characteristics are: "time the victim is in water" and "the fuel consumed by the patrol boat". This process continues with random events and responding patrol boats during a simulated 168 hour week. The significant measures are totaled. The Coast Guard decision makers can use these measures to compare alternative fleet mixes. Our DSS will not produce an optimal fleet mix, yet it will provide the user with valuable information for comparing alternatives.

This chapter has presented a view of the complexity of the fleet mix planning problem and some of the factors that are considered in the decision process. One alternative solution approach to the fleet mix planning problem, and two Coast Guard patrol boat performance evaluation tools were discussed. This research builds on the previous research, and presents our DSS for fleet mix planning. Chapter III will discuss our design for the patrol boat fleet mix planning DSS.

III. THE DECISION SUPPORT SYSTEM

This chapter presents our design for the fleet mix planning decision support system. We begin developing and structuring the DSS by exploring four main issues relevant to it: the application theory, the conceptual approach, the representations and the operations of the system. Each of these areas will be discussed in the first section of this chapter. The second section of this chapter will examine and present methods for evaluating and comparing fleet mix alternatives.

A. DSS DESIGN

1. Application Theory

The application theory answers the question "What will this system be used for, how can it be useful, and why is it needed?" Broadly, the purpose of a DSS is to assist decision makers regarding alternative courses of action. In the context of fleet mix planning, what is needed is a DSS that can tackle the problem in parts. The DSS can then be immediately useful, without having to solve the entire problem. The DSS can be enhanced until the problem is sufficiently solved or the investment of time does not add significant value. This incremental, iterative process to the DSS approach will provide the decision maker with a system that is of immediate use. It can be expanded as organizational confidence grows and as its results are accepted.

Also, the DSS provides the user valuable information about various facets of fleet planning in one easily accessible system. Information about

ships, costs, crew sizes and homeport facilities will be available through the DSS.

a. System Use

The intended application of the system can be classified into three broad categories. First the system will provide features to evaluate various characteristics of a fleet mix alternative that bear on the decision. Second, the system will provide features to create and analyze data scenarios to evaluate important attributes of the fleet mix alternative. A solution obtained from analysis of many possibilities should account for much of the uncertainty in the environment, (discussed in Chapter II) and should be robust and less sensitive to changes. Third, we will emphasize system features that allow users to justify decisions that may be reached on the basis of these results.

b. Need for Decision Support

The primary goal of this research is to provide a tool that meets existing needs in the Coast Guard. A listing of the Coast Guard's needs for support in the acquisition process is provided in [Ref 3:p. 8]. Some of those needs are consistent with the objectives of this research and are quoted below:

- An existing need to replace an aging fleet of capital assets.
- A policy and political environment in which funds are in short supply.
- Vessel acquisitions are complex and difficult, and require years of effort and planning. (Typically 5-10 years elapse between initiation of an acquisition project and actual construction of new assets. Ships remain among the most complex of human artifacts.)
- Complexity and difficulty are increased by new technology, changing mission requirements, and the fact that fleet mix planning becomes more critical with limited resources.

- Analysis of alternatives has been weak and previously done without extensive management science techniques.
- Shortage of personnel; existing personnel are overextended and must answer many difficult questions from the Department of Transportation, Congress, etc. The Coast Guard requires a fast, accurate, and consistent way of responding.
- The costs of mistakes and vagueness are high, with the costs measured in credibility with the Department of Transportation and Congress, and in dollars paid to contractors for Coast Guard mistakes and to attorneys for litigation support. [Ref 3:p. 8-11]

The DSS provides decision makers with a tool that will facilitate the evaluation of fleet mix alternatives. It will have the ability to perform ad hoc queries on data about fleet mixes. In addition, the DSS breaks the complex fleet mix problem into manageable and understandable parts for the user.

2. Conceptual Approach

We have discussed the application theory of the DSS in the above paragraphs. To help clarify and illustrate how the system should be delivered and what the system should look like, we discuss the conceptual approach underlying our system. Our conceptual approach will be to:

- develop a set of measurable key characteristics of a fleet mix.
- group the characteristic measures into the three primary measures: cost measures of a fleet mix alternative, activity measures of a fleet mix alternative, and performance measures of a fleet mix.
- present the characteristic measures in a hierarchical environment that uses a hypertext presentation system [Ref 9:p. 3-8].

The three types of measures entail: a) cost measures that will be provided by the Coast Guard, b) activity measures that will also be primarily provided by the Coast Guard, and c) performance measures that produced using the simulation model developed in our DSS.

3. Representations

The DSS is able to represent a diverse set of information such as cutters, homeports and events. In particular, the following items will need to be represented in the system.

- Characteristics of a ship.
- Homeport pier facilities and location.
- Coast Guard Districts.
- Components of a fleet mix.
- Characteristics of an event.
- Simulation inputs.
- Rules[5] about dispatching cutters to a mission.
- Models and formulas.

The DSS will provide internal and external representations in order to capture the information required.

a. Internal Representations

The internal representations of the DSS will include data structures and rules in the knowledge base. In particular, relational data tables will be used to store data about the ships, homeports, pier facilities, districts, events, and fleet mixes. A model base will be used to store the rules and models required by the DSS.

b. External Representations

The external representations of the DSS will include data entry forms, tabular reports, icons and buttons in a hypertext environment. Data

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[5]Rules are used to represent the logic required to take actions such as assigning ships to events. Rules decide the proper action to take when an event is called and executed.

entry forms will be used to allow the user to input the data required about a new ship, a fleet mix, and a simulation run. Tabular reports will be used to display simulation results, fleet mixes, homeports in a district, and simulation inputs. Icons will be used to represent types of ships and events. Buttons will be used to represent navigational commands, start-up commands and execution commands.

4. Operations

Operations on the information structures are supported by the following user capabilities.

- Perform simulations on selected fleet mixes and scenarios.
- Aggregate simulation results.
- Present the results in a final results format.
- Create a new ship, an alternative fleet mix, or a scenario.
- Modify ship characteristics, homeports, districts, fleet mixes, performance tempo, and sea state conditions.
- Print reports as required: Simulation results, Cost and Performance Measures, and data retrieved from a database.

In summary, we have defined the four main issues relevant to the development and structure of the DSS. This section also discussed what the user will use and see in the DSS. In the following section, the emphasis shifts to the functionality of the DSS and how the system will achieve the items discussed above.

B. FLEET MIX EVALUATION

The DSS provides results for alternative fleet mixes in three significant attributes. The first attribute is the cost of the fleet mix. The second is the potential activity of the fleet mix. The third is the performance of the fleet mix.

1. Lifecycle Cost

The OMB Circular A-109 requires an analysis of the lifecycle cost of a proposed patrol boat capability replacement [Ref. 10:p. 4-14]. The lifecycle cost for the fleet of patrol boats is more difficult to define, since some patrol boats are nearing the end of their service life, some are new, and some have not been built yet. The lifecycle cost for one vessel is the sum of the costs in the following categories:

- <u>Ownership costs</u> include acquisition cost, mid-life refurbishment costs, and salvage /disposal costs.
- <u>Operating costs</u> include fuel, oil, lubricants and hotel costs (food, blankets).
- <u>Maintenance costs</u> include preventive and corrective maintenance costs.
- <u>Personnel costs</u> include the standard billet costs for the assigned crew and designated support personnel. [Ref. 11]

These costs are distributed throughout the service life of the vessel. To provide a means of comparing alternatives, the present value of the cost is computed using discount factors and is called the lifecycle cost. The annualized lifecycle cost is the uniform annual payment over the service life of the vessel equivalent to the lifecycle cost. The DSS computes the total of the annualized lifecycle costs for the fleet mix alternative.

The individual components for the cost attribute within the current version of the DSS will be entered by the Coast Guard users. A spreadsheet application is planned for computation of the lifecycle cost. The values for cost in each category and the timing of the cost will be entered by the user.

2. Activity

The attribute of potential activity relates to the time available during a year for each of the patrol boat's required tasks. These activities include

maintenance, standby, patrol and crew rest. The user can enter and modify numbers in each category for a specific class patrol boat. The DSS computes the activity for the entire fleet mix alternative.

3. Performance

Our approach evaluates performance using a computer simulation. The method measures performance of a fleet mix of cutters in a situation that simulates the operating environment for the patrol boats. The basic idea of the simulation approach is simple. Each alternative fleet mix is evaluated under a scenario representing a fragment of real-life demand on the Coast Guard's fleet. This evaluation is performed by simulating responses to random events, and measuring the costs and performance of the results of these responses. By repeating this evaluation over a variety of scenarios that could represent future demand (given the information known today), these results will represent a robust and fair evaluation of the fleet mix. By evaluating each fleet mix under the same set of scenarios, we can get a comparative evaluation of the alternative fleet mixes.

Several models are needed within the simulation process. These are an event manager for random event generation, a dispatch model for selecting the cutter to send on a mission, an intercept model to compute the dispatched patrol boat's course in order to intercept a suspected vessel, a ship movement model to update each ship's position at each interval and an operations manager to control changes to a vessel's assignment.

a. Event Manager Model

The event manager determines if an event occurs during a time interval. First, the model generates a random number. If the number falls

within a certain range, no event occurs. If the number is in another range an event occurs. A second random number is used to select the type of event, its location and other event details. The details for the events are drawn from a table of typical patrol boat events such as SAR cases and drug boat traffic.

b. Dispatch Model

The dispatch model uses information about the most recent event to assign the appropriate cutter to the case. The location of the event (such as a ship in distress) and the type of event are the key variables. This model was developed through interviews with various Coast Guard officers. The event manager first makes a list of patrol boats available for assignment to the mission. The SAR mission has the highest priority, and a vessel could be diverted from another lower priority mission if necessary. Patrol boats in the standby condition (inport) will be directed to respond if required. Patrol boats are not considered if they have insufficient fuel or are due to complete a patrol within a day. In the case of a moving target, the vessel that is in the best position to intercept the moving vessel (normally a drug boat) is assigned. In the case of SAR, the vessel that can get to the scene first is assigned to a SAR case. Other types of missions are assigned to the closest vessel with the capability.

c. Intercept Model

The intercept model uses information about the location, course and speed of the vessel to be intercepted, the location, and maximum speed information of the patrol boats eligible for assignment. Typical geometry of the situation is shown in Figure 3-1. The position of ships is indicated by x and y coordinates on a grid representing the Coast Guard district. The goal is

to select the cutter that is in the best position to intercept the drug boat, and compute an intercept course for the selected cutter. The problem is solved using the following steps.

- Assumptions: The computations assume the position of both vessels are known, the target vessel course and speed are known, and that the target doesn't change either course or speed. In reality if target course or speed changed, the patrol boat would compute a new intercept course.
- The basic approach to finding the intercept course relies on a line-of-sight diagram (Figure 3- 2). The distance to the target vessel and the bearing to the target vessel is determined. The target course is plotted on the upper end of the diagram, and the speed is indicated. The target has speed across the line-of-sight and speed in the line of sight. By selecting a course for the patrol boat that has the same speed across the line-of-sight, the patrol boat will achieve the fastest intercept of the target vessel. Note that some of the patrol boat speed will be in the line-of-sight, tending to reduce the range to the target. The process is illustrated below.

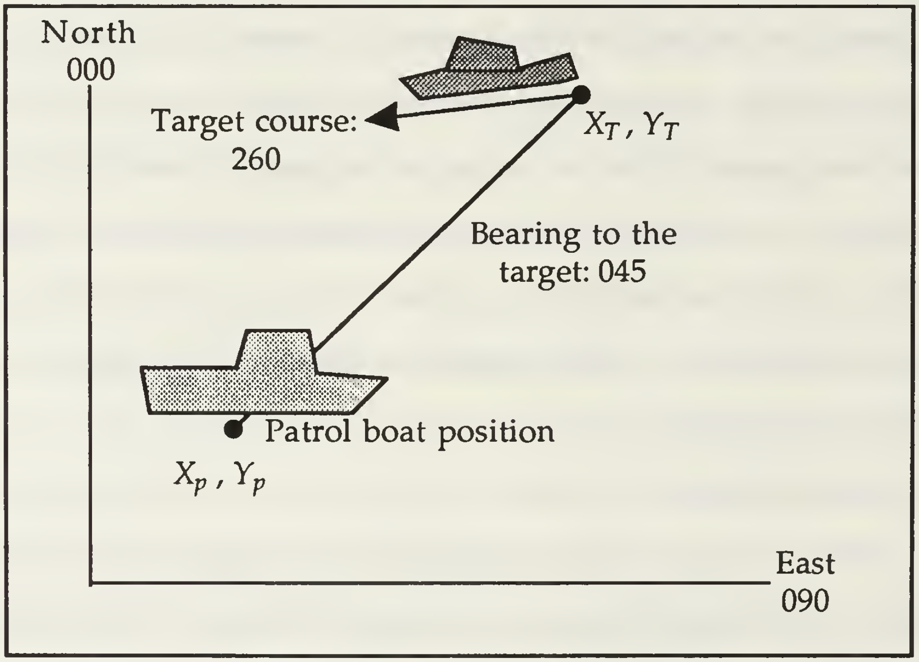

Figure 3-1 Geometry of Target Intercept.

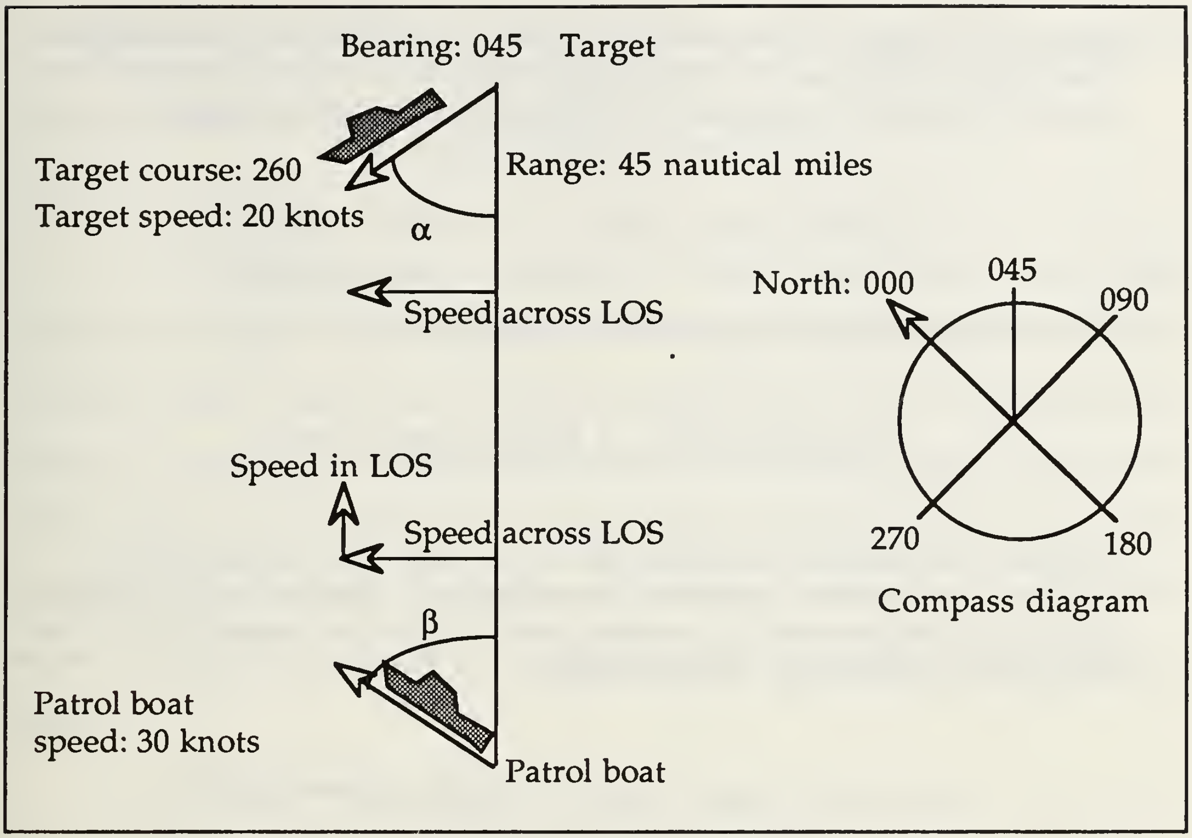

Figure 3-2 The Line-of-Sight Diagram for Determining Intercept Course.

- Compute the range between the vessels.

$$Range = \sqrt{(X_p - X_t)^2 + (Y_p - Y_t)^2}$$

- Compute the bearing to the target vessel.

$$Bearing = 90 - \arcsin\left(\frac{Y_t - Y_p}{Range}\right)$$

• Compute the angle (α) between the target course and the line-of-sight. This angle will be used to compute the target speed across (perpendicular to) the line-of-sight and speed in the direction of the line-of-sight.

$$\alpha = 180 - (Target\_course \; - \; Bearing\_to\_target)$$

• Compute the target speed across the line-of-sight.

$$Speed\_across\_LOS \; = \; Target\_Speed \; \times \; \mathrm{Sin}\; \alpha$$

• Compute the angle (β) between the line-of-sight and the patrol boat course. This course is selected to have the same speed across the line-of-sight as the target vessel. The other condition for the course is that it be closing the target rather than opening.

$$Patrol\_boat\_speed \; \times \sin \beta = Target\_speed \; \times \sin \alpha$$
$$\beta = \mathrm{Arcsin}\left(\frac{Target\_speed. \; \times \mathrm{Sin}\; \alpha}{Patrol\_boat\_Speed}\right)$$

• Compute the patrol boat course. There are two cases: either a target course on the left side of the line-of-sight (port) as shown in Figure 3-2 or the target course on the right side of the LOS (STBD).

For a Port LOS: $Patrol\_boat\_course \; = \; Bearing\_to\_target \; - \beta$

For a STBD LOS: $Patrol\_boat\_course \; = Bearing\_to\_target \; + \beta$

• The time to interception is computed. Again there are two cases: If the target is opening (we see his stern), the speed components subtract. The patrol boat will be chasing the target. The second case is a closing target (we see his bow)as illustrated in Figure 3-2, and the speeds add as shown below.

$$Relative\_speed\_in\_the\ LOS = Target\_speed \times \cos\alpha + Patrol\_boat\_speed \times \cos\beta$$

$$Time\_to\_intercept = \frac{Range}{Relative\_Speed\_in\_the\_LOS}$$

The intercept model computes the time to intercept for each patrol boat that is eligible for assignment. The patrol boat with the minimum intercept time probably will have the best opportunity and geographic position to intercept the target and perform the mission. Other patrol boats could have a very long intercept time if they are chasing the target from behind. The boat with the minimum intercept time is assigned to the mission, its speed is changed to maximum and it' course is set to the intercept course.

d. Ship Movement Model

The ship movement model computes a new position each interval for any vessel (patrol boats and drug boats) based on its assigned course, speed, and the previous position. The positions are computed using the following relationships:

$$X_2 = X_1 + (X\_component\_of\_speed \times Time)$$

$$X_2 = X_1 + Cos(90 - Vessel\_course) \times (Vessel\_speed) \times T$$

$$Y_2 = Y_1 + \mathrm{Sin}(90 - Vessel\_course) \times (Vessel\_speed) \times T$$

- where T is the time interval (one hour)
- $(90 - Vessel\_course)$ is the conversion of the vessel's course measured in degrees relative to north to an angle relative to the X axis as shown in the Figure 3-3 below.

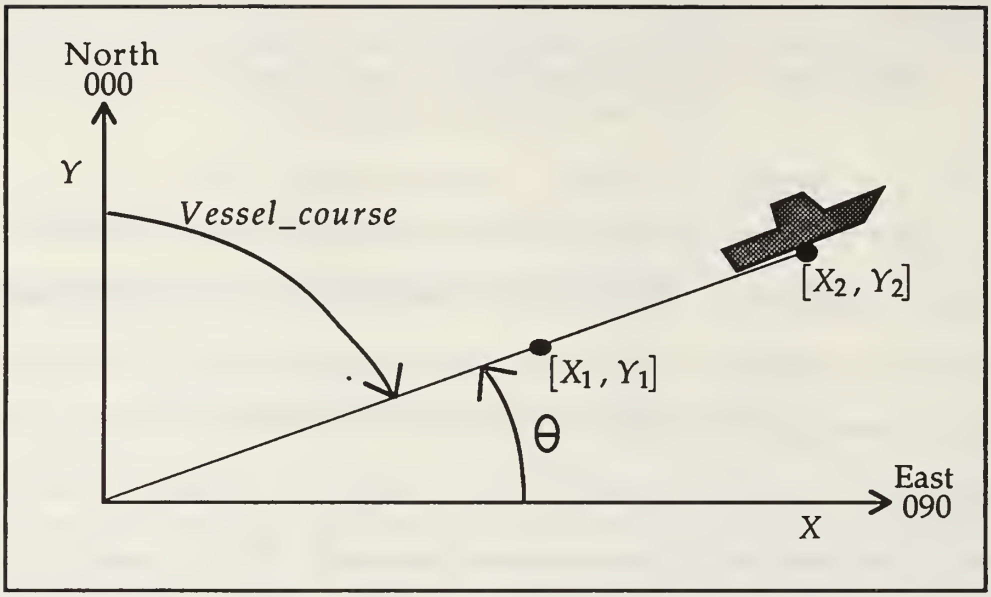

Figure 3-3 Geometry of Vessel Motion.

e. Ship Operations Manager

Some situations will require a change in the patrol boats operating conditions. The dispatch and intercept models make changes to course and speed in response to a new mission. The ship operations model makes changes in all other conditions. Some of these conditions are that the patrol boat is low on fuel and must refuel, or that the patrol boat has completed its patrol and returns to port, or the patrol boat reaches it's destination and must slow to render aid. The need for change is normally detected by the ship movement model, as it routinely checks the quantity of fuel remaining, days underway and the distance remaining to the destination. When the ship operations model is called, a parameter is set to indicate the present condition and the change necessary.

We have discussed the design of the DSS and the methods for evaluating fleet mix performance using the DSS. Chapter IV presents our implementation of this design in an operational DSS prototype.

IV. IMPLEMENTATION OF FELIX

The system design described in Chapter III has been implemented in a prototype DSS called Felix. This chapter presents the implementation process of the DSS and highlights the major components of the system. In addition, transfer of data and control between three different software products is discussed. A brief description of the hardware and software selected for the implementation of the DSS is first introduced.

Initial requirements for Felix were that the user interface be built with a hypermedia software application, and that a relational type database be used. Felix is implemented and runs on the Macintosh® II family of machines with eight megabytes of random access memory. The database was developed using a relational DBMS labeled ORACLE® (version 1.2 published by Oracle Corporation), the interface was developed using SuperCard® (version 1.5 developed by Silicon Beach Software), and the model base was developed with Nexpert Object® (version 2.0 published by Neuron Data).

A. APPLICATION INTERFACES

Ensuring that all three products could communicate with each other was the most important factor in the selection process. Oracle is a relational database that is specifically designed to take advantage of a hypermedia software application. SuperCard is a newly developed hypermedia software that advances the original Hypercard® environment made famous by Apple®. Nexpert is an expert system shell that provides interfaces for several of the well known software products. We will briefly discuss how

each software package communicates with the other two and how they provide the interface process that is required for the implementation of Felix.

1. Oracle

Oracle databases are managed by the Oracle Relational Database Management System (RDBMS). The data within the tables is accessed by using commands issued in Structured Query Language[6] (SQL). Oracle provides additional features to interface with other software applications. The two features required to interface with SuperCard and Nexpert are addressed below.

*a. Hyper*SQL*

Hyper*SQL is an Oracle application which allows the database tables to be accessed from a hypermedia software application, such as SuperCard. The access commands (initiated from SuperCard) allow the user to initiate Oracle database operations, such as starting and stopping Oracle, logging on to a database, creating database objects, performing queries, inserting and updating data, and monitoring error and control messages through Hyper*SQL scripts[7] [Ref. 12:p. 4-1].

*b. Pro*C*

Pro*C provides an environment in which the user can use a C language application (such as Nexpert) to access the database tables. The C

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[6]SQL is an English-like, non-procedural language defined by IBM™ Research and introduced to the commercial market in 1979.

[7]A script is basically an informal small computer program written in the appropriate language that executes whenever the user takes some action. For example, the user may click a mouse button or select a command from a menu to commence an action.

language program is translated by the Pro*C precompiler into equivalent SQL commands. Some of the features of the Pro*C precompiler are:

- Each SQL statement is automatically translated to the equivalent runtime library calls, reducing programming time.
- A single Pro*C program can be created to operate with data from different Oracle databases.
- Multiple Pro*C programs can be separately precompiled and executed together in the same application [Ref. 12:p. 9-1].

2. SuperCard

SuperCard uses a scripting language called SuperTalk to perform internal operations. An external command facility (XCMD) allows developers to write SuperCard applications that communicate with external programs including Oracle and Nexpert [Ref. 9:p. 145-147].

a. XCMD for Oracle

When SuperCard encounters the external command EXECSQL in a script, the remaining program line is passed from SuperCard to Oracle through the Hyper*SQL interface. An example of an EXECSQL command embedded in a script would be: "EXECSQL Select SEQUENCE from SIMULATION_QUEUE."

b. XCMD for Nexpert

SuperCard has two way communications with Nexpert by using the external command NXP. In addition, the Nexpert Dynamic Library (NDL) and the Nexpert Handler Interface (NHI) files must be installed in the System folder. NDL provides access to the system features of Nexpert from other programs and the file NHI is the file that passes message between SuperCard and Nexpert.

3. Nexpert

Nexpert provides the developer several flexible methods for communication with external programs and databases. The Nexpert Database bridge and HyperBridge provide an easy interface to Nexpert compatible applications. The database bridge supports a wide variety of file and database formats but we will discuss only the process for linking Nexpert with Oracle [Ref. 13]. The Nexpert HyperBridge consists of several modules which enable the Nexpert Dynamic Library to be accessed directly from SuperCard scripts using XCMD commands [Ref. 14:p. 1-20].

a. Database Bridge

The Nexpert Database bridge is invoked when Nexpert processes a Retrieve or Write command. The Retrieve command moves data from Oracle into Nexpert's working memory, the Write command moves data from Nexpert's working memory to Oracle. The bridge does much more than simply transfer data; it also transforms it between Nexpert's class-object-property representation and Oracle's format [Ref. 13:p. 57]. The specific implementation process can be found in the Nexpert Object Version 2.0 Database Integration Guide. Briefly, the implementation process uses the Nexpert Database Editor to list the available database interfaces already built into Nexpert. The keyword ORACLE is used by Nexpert to designate an Oracle database. The keyword is used before each call to the appropriate database.

b. Nexpert HyperBridge

The Nexpert HyperBridge integrates Nexpert to other applications through its runtime library. The Nexpert Handler Interface (NHI) is the interface from Nexpert to the SuperCard script. This handler is used to return

messages to SuperCard. The NDL receives the NHI message and translates the message into the proper code for use by SuperCard.

The interfaces between programs are an important part of developing any program and was a critical one in the success of Felix. We have introduced the intricate process of connecting the three programs selected in building our DSS. Specific details of each were omitted but the important interface commands were briefly discussed. In the following section, we present the modules within Felix.

B. FELIX MODULES

Felix is implemented in three components that are directly related with the three selected software products. The first component is the Oracle database. The second component is the user interface that was developed with SuperCard. The third component is the model (including math and deductive models) base, developed in Nexpert. Figure 4-1 illustrates the design of Felix. In this system, the user will work directly with the user interface. The user interface will access the DBMS and knowledge base as required by the user. The DBMS will access the appropriate data files in storage. The knowledge base will access the models, objects and rules as needed to complete the task requested by the user. In addition, the knowledge base may require a data file and will access the DBMS. Each of these three components has several interface modules that complete separate tasks within the component. We explain each component's internal modules and its external relationship with the other two major components in the following paragraphs.

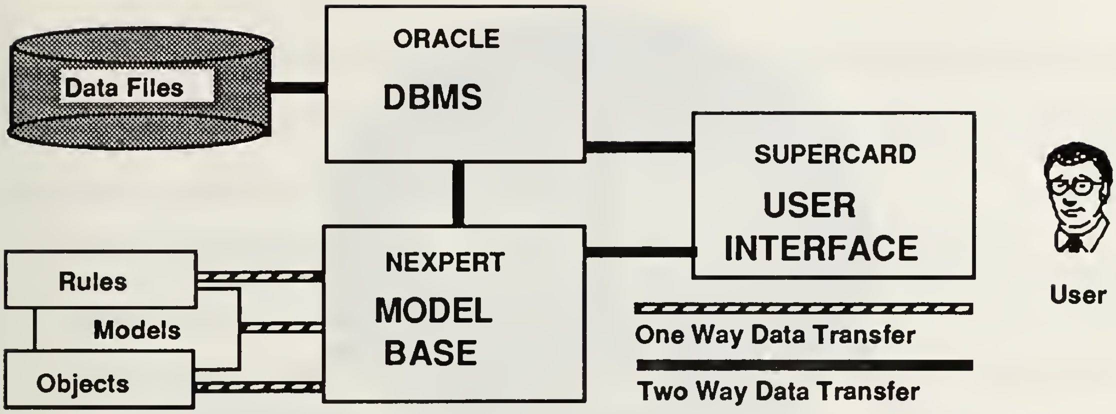

Figure 4-1 Configuration Layout of FELIX.

1. Oracle Database

The database management system (DBMS) consists of a database with data tables that store the DSS data. The database is the passive component in the system. It only provides a data repository service to the other components. Figure 4-2 illustrates the external relationships with the user interface and the model base, and the internal modules.

a. External Relationships

The tables stored in the database are used by the user interface and the model base. For example, the model base requests values from a table stored in Oracle and uses that data as inputs to a model or rule. Afterwards, the output data of the process is transferred to the database for storage. The relationship with the user interface is similar. The user requests information from the database. The data is transferred and returned to storage upon completion.

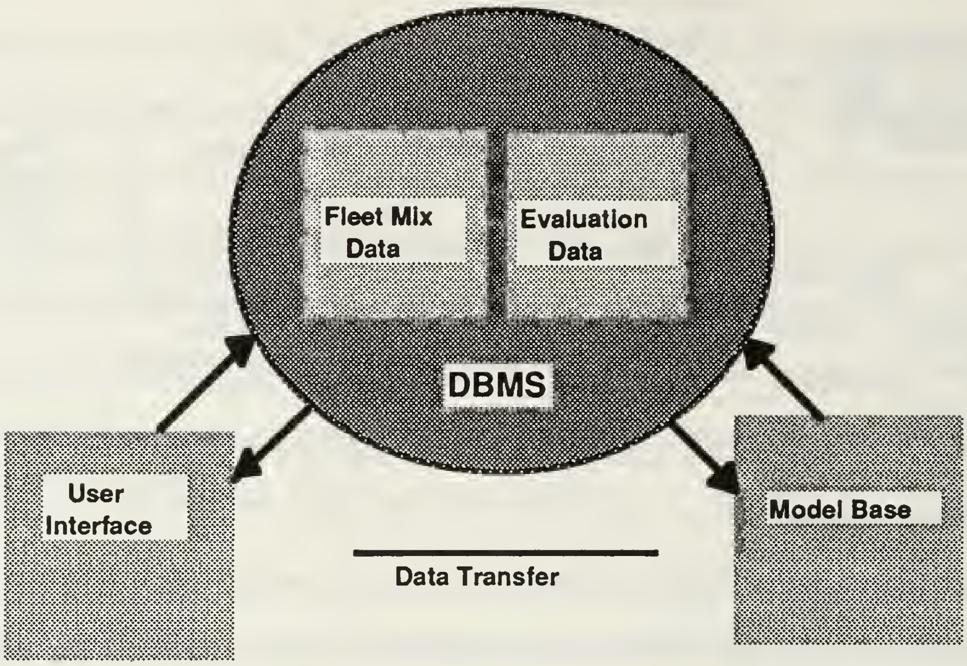

Figure 4-2 DBMS Layout Design.

b. Internal Modules

The data within the database is classified into two general groups, Fleet Mix data and Evaluation data, each of them having several tables. In the Fleet Mix data group, the tables include data that pertain to the Coast Guard cutters. Examples of these data tables are:

- Cutter Characteristics Table: Captures important data about a specified cutter, including Max Speed, Length, Beam, and several others.
- Fleet Mix Tables: Captures the type and quantity of cutters that comprise the specified fleet mix, including WPB-80's, WPB-82's, WPB-110's and WPB-120's.
- Homeports Table: Captures the data required to identify the location and facilities of a homeport, including the City, State, District, Restrictions, and Limitations.

In the Evaluation data grouping, the tables store required data needed to run the evaluation process and the results from an evaluation. Examples of this type of data are:

- Simulation Queue Table: Captures information about the next simulation to run, including Fleet Mix selected, District, Sea State, Sea State Trend and Operation Tempo.
- Events Table: Captures information about six different possible events that could occur in a simulation run.
- Simulation Results Table: Captures information about the results of the simulation, including SAR Missions, ELT missions, Failed SAR Missions and several others.

2. User Interface

The Felix user interface is an interactive system designed to allow the user to quickly master Felix. The primary design goals are to provide the user a friendly easy system and to provide a system that can be easily enhanced as the need arises [Ref.15:p. 9]. In our first goal, we refer to the user interactions with the tasks and sub-tasks that must be carried out within Felix. Task functionality is centralized so that the user can quickly return to a familiar section of Felix (mainly the main menu). Excessive functionality is kept to a minimum so as not to confuse or frustrate the user. The screens presented to the user are similar and consistent in format and enhance the user's comfort with Felix as he quickly masters the program. The second goal of ensuring adaptability of the system refers to the quest for a modular design and correct performance.

The user interface design is displayed in Figure 4-3. The external relationships will be discussed in the next paragraph, followed by the internal modules of the user interface.

a. External Relationships

The external relationship of the interface with the DBMS is similar to the data transfer process discussed in the previous section. The user interface calls a table from the DBMS for the user to view, print or modify. In addition, the user interface transfers new data to the DBMS as created by the user. The data could be from any of the tables within the database.

The external relationship with the model base is a program control transfer. The call to the model base will relinquish control of the system to the Nexpert program. The model base returns control to the user interface upon completion of the called evaluation process.

b. Internal Modules

Within the user interface there are four modules: the Online Help system, the Data Retrieval/Insertion/Update module, the Report Generator, and the Model Base Control. The four modules are briefly discussed below.

The Online Help System is found on each of the display screens within the user interface. The user can obtain additional help information by pressing the Help button provided at the bottom left corner of each screen. A scrolling window will appear containing information that explains each option available on the displayed card. An additional feature of the Online Help system is the presence of additional bottom row buttons that provide the user with an easy method of returning to the main menu.

The Data Retrieval/Insertion/Update module allows the user to retrieve the tables within the database and modify them as necessary. Additions, deletions and changes are common requirements in any system,

and are easily performed in Felix. Additional features of this module are the Start/Stop buttons for Oracle and the Oracle Log On process.

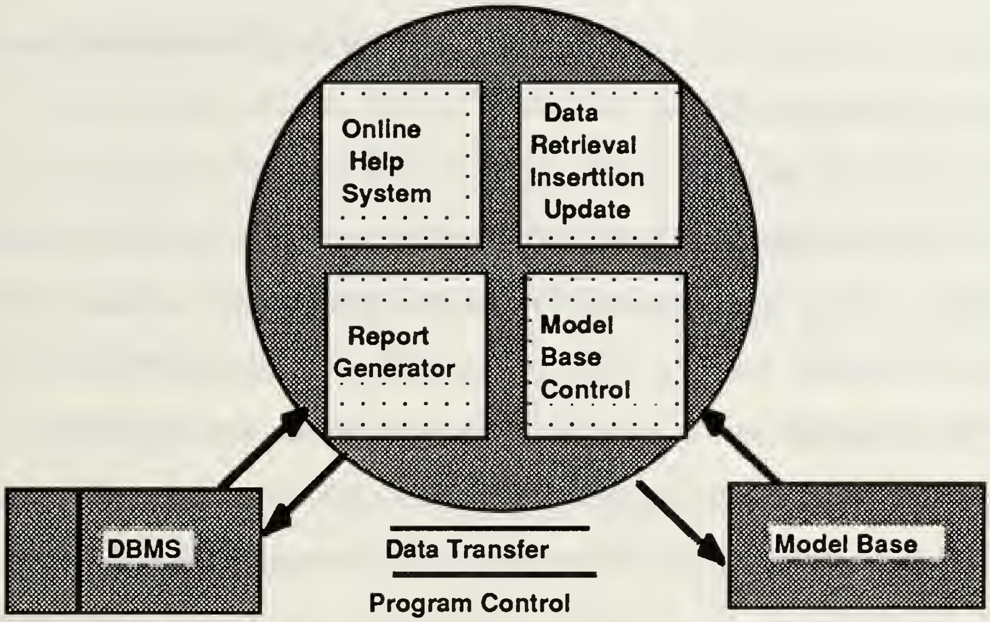

Figure 4-3 The User Interface Layout.

The Report Generator provides the user with the ability to print different reports. Examples of the items available for printing are:

- Aggregate Fleet Results: The report that lists the final measures to be used by the decision maker.
- Homeports: A list of all the homeports used by the Coast Guard and the facility limitations.
- Fleet Mix: A list of the select fleet with information about the vessels and homeport placement.
- Simulation Result: List the measures of a single simulation run.

The Model Base Control provides the user the ability to initialize Nexpert and select the evaluation process. The evaluation process is started when the user selects a button on the Model Base Control card. The user

initiates fleet performance evaluation by selecting the Perform Simulation button. Similarly, the user initiates aggregate results of performance simulations by selecting the Aggregate Results button. Buttons are provided for Evaluate Costs and Evaluate Activity, but this feature was not provided in the initial prototype version.

3. Felix Model Base

The model base for the DSS provides two types of environments for knowledge based applications: the development environment and the Nexpert Dynamic Library. The development environment is the more powerful of the two and is used to build and modify new applications. These applications are stored as individual program files to be accessed as required. The development environment also provides templates for defining rules, classes, and objects. In addition, it provides the knowledge processing function that can be controlled step-by-step if necessary for testing. In comparison, the Nexpert Dynamic Library provides access to the knowledge processing features of Nexpert, but does not provide the editing features.

Nexpert uses rules to represent intelligence, and objects to represent entities in the real world. The logic of the model is written using rules that reference objects such as patrol boats and object properties such as speed of the patrol boat. The logic for the models in the model base was presented in Chapter III.

The model base in Felix, illustrated in Figure 4-4, is a Nexpert application with a knowledge base file for each evaluation process. The user interface calls the Nexpert Dynamic Library to perform evaluation of the fleet mix using the proper knowledge base file. The external relationships section

describes the purpose of the model base and its place within the DSS. The internal modules section describes the operation of the models within the model base.

a. *External Relationships*

The model base is called by the user interface to perform various types of fleet mix evaluation and analysis. These calls are basically program control calls. Control of Felix is relinquished by the user interface and is given to Nexpert as the selected evaluation is being processed. Upon completion, control is returned to the user interface.

The relationship of the model base with the database is a basic data transfer. The models retrieve data from the database and write data to the database as required for analysis. This process is controlled by rules within Nexpert.

b. *Internal Modules*

The internal logic of the evaluation modules was presented in Chapter III. Specific aspects of the model base implementation are discussed below. The simulation and aggregation models are written using Nexpert and are stored as a Nexpert knowledge base. The activity and cost modules, although not implemented, are included for discussion.

The simulation model is called by the user interface and performs the following steps:

- Read in simulation data
- Read in fleet mix data
- Read in Event data
- Perform the first simulation run
- Write results to the simulation results table.

* Repeat the above process until all runs in the simulation queue have been performed. Nexpert returns execution control back to the user interface.

The result aggregation module is also called from the Model base control card in the user interface. The aggregation performs the following steps:

* Read in the data for the fleet mix being aggregated.
* The simulation results are first combined by district.
* The district results are then combined for a fleet.
* Upon completion, the results are stored in the database and program control is passed to the user interface.

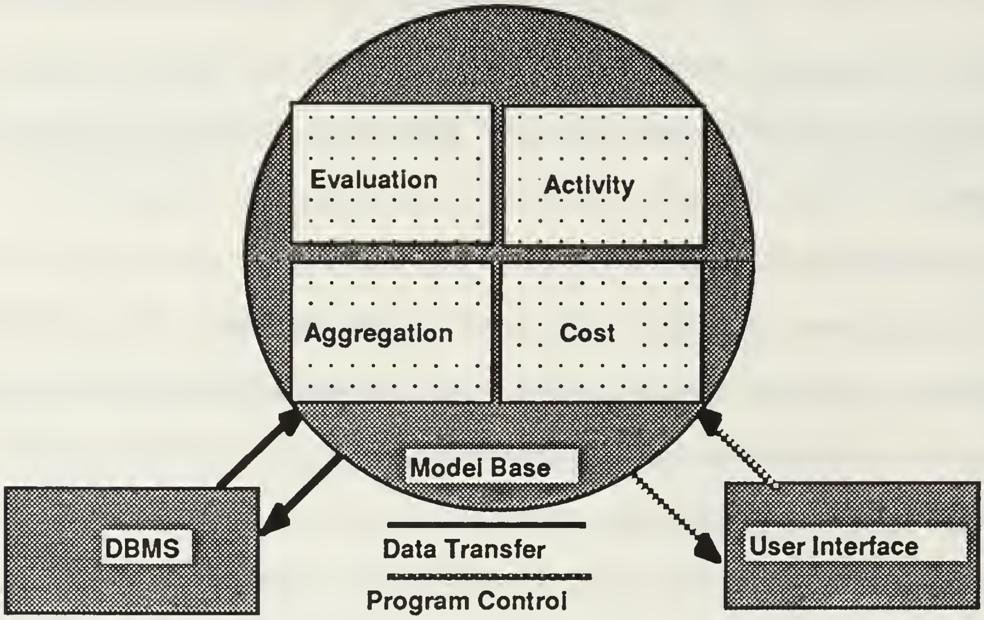

Figure 4-4 The Model Base.

The activity module will evaluate the measures that would determine if the fleet could meet the projected modes of operation. The evaluation process will include assessing maintenance hours, patrol hours,

crew relief hours, and stand-down hours. The focus will be to analyze the extent to which a selected fleet mix can provide the required hours for each phase of a cutter's lifecycle.

The costs module will evaluate the costs associated with a fleet mix. Some of these costs include lifecycle, acquisition, operations and maintenance (O&M), and manning.

This chapter has presented a description of the DSS prototype developed as a part of this research. The application interfaces, user interface, database and the model base were described. The next chapter will present a user's point of view and will examine the results of a sample simulation.

V. FLEET MIX ANALYSIS USING FELIX

The procedures for using Felix to evaluate alternative fleet mixes are presented in this chapter. In addition, we present considerations that should help the user analyze the results of a simulation run.

A. WORKING WITH FELIX

In this section, we illustrate the steps required to set up and run a performance evaluation of fleet mix alternatives. Specifically, we address how the user will:

- define a new fleet mix.
- select parameters as initial conditions for the simulation process.
- perform the simulation.
- analyze the results.

1. Initial View

Initially, the user will view the main menu of Felix. This is illustrated in Figure 5-1. Several operations are possible from this screen. We will only discuss the process of stepping a user through a typical simulation process. Other options available to the user are explained in the Felix user's manual.

The first action required by the user will be to start the Oracle database by selecting the Start Oracle button. Internally, the procedures described in the previous section will occur and the link between the user interface and the database will be established. The user may define a new fleet mix alternative, modify a fleet mix alternative or continue with the simulation setup of all fleet mix alternatives already defined. To build a new fleet mix

alternative, the user selects the Build Fleet button. Felix will display the screen illustrated in Figure 5-2.

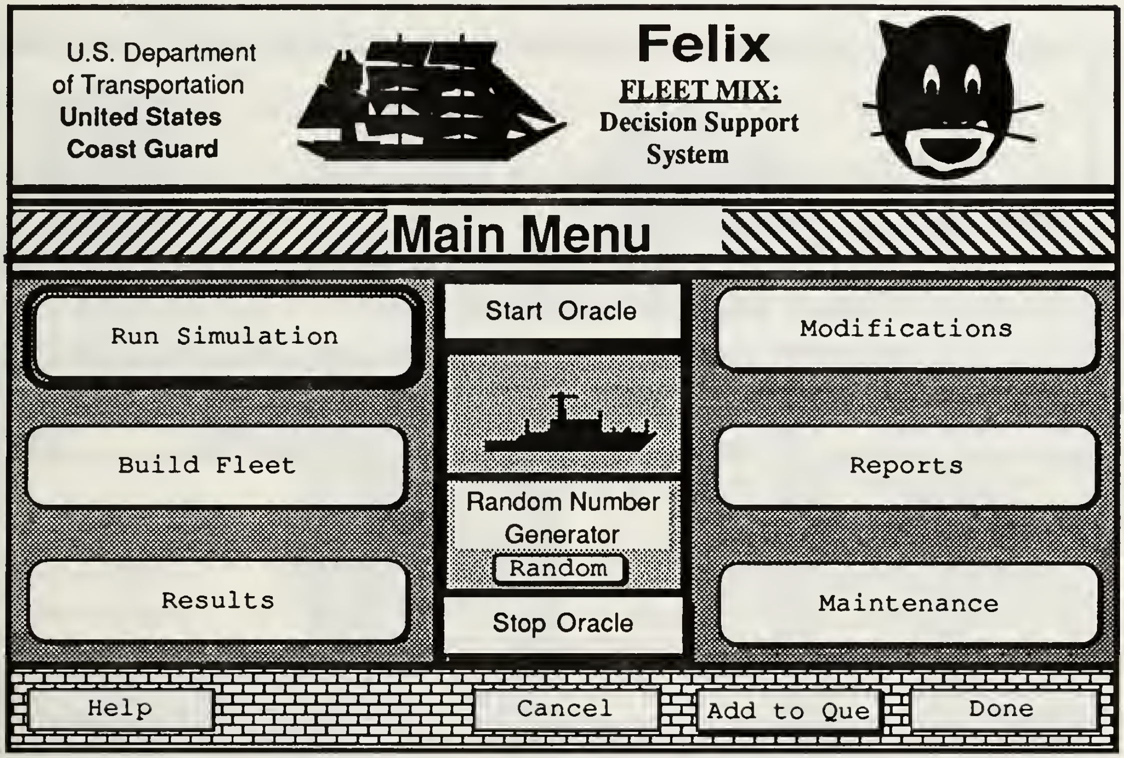

Figure 5-1 Main Menu in Felix.

2. Build a Fleet

Two screens are used to build a new fleet. In the first screen, the user assigns a fleet mix number and selects the number of patrol boats for each class. When completed, the user selects the Done button; the second screen in the Build Fleet process appears. The user assigns each vessel to one of the listed patrol boat homeports. The homeports are automatically linked to the proper Coast Guard district within the DSS. The result is a fleet mix alternative that defines the vessel class, homeport and district for each boat. Up to five fleet mix alternatives can be defined and stored in the DSS in this

manner. Upon completion, the user selects the done button and is returned to the main menu.

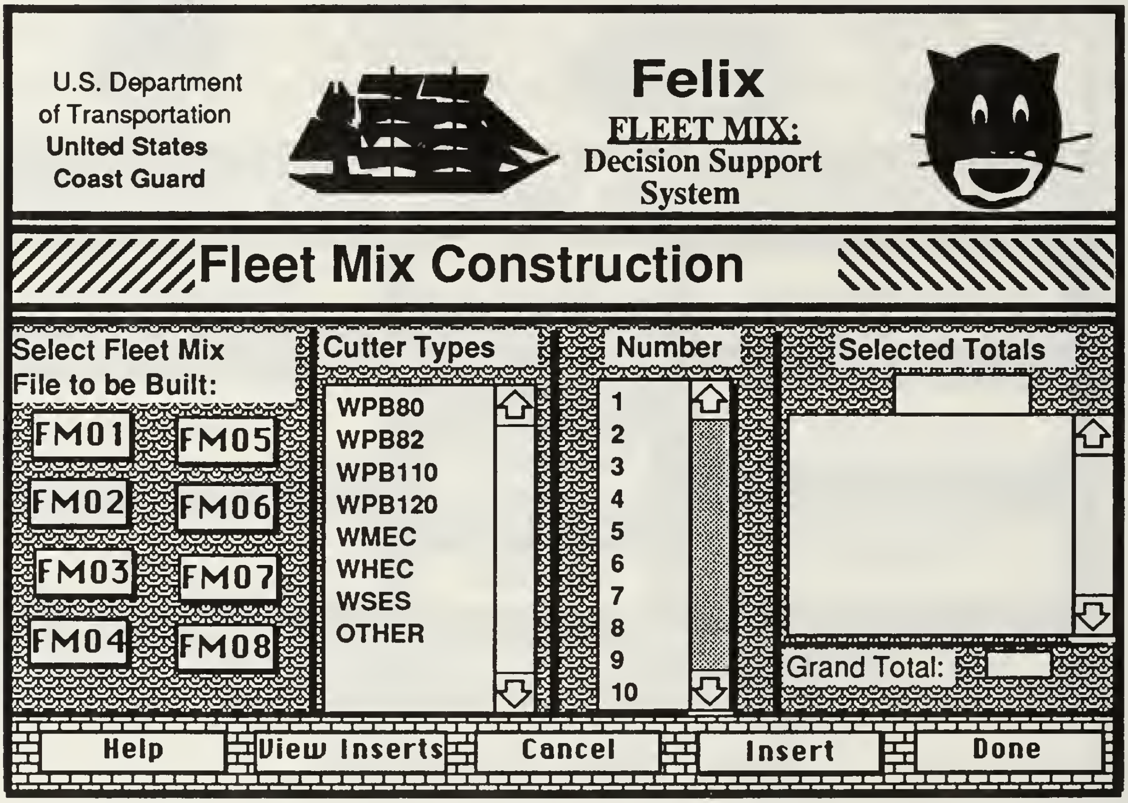

Figure 5-2 Build Fleet Mix Screen.

3. Simulation Process

To set up the simulation, user selects the Run Simulation button on the main menu. Felix will display the Simulation Input screen as illustrated in Figure 5-3. Each simulation run is defined as follows:

- select one of the eight fleet mix alternatives.
- select a district for evaluation.
- select the initial sea state (weather condition).
- select the trend in the sea state (how the sea state changes during the run).

- select the tempo of operation (a parameter which will eventually control the rate of random event occurrence).

The parameters for the first simulation run are now defined and are stored in the Simulation Queue data table. The user may enter additional simulation runs, varying the fleet mix number, the district and initial conditions for the simulation. One requirement is to evaluate each fleet mix alternative in each district under a variety of conditions. Another requirement is to evaluate each fleet mix alternative under the same set of simulation parameters.

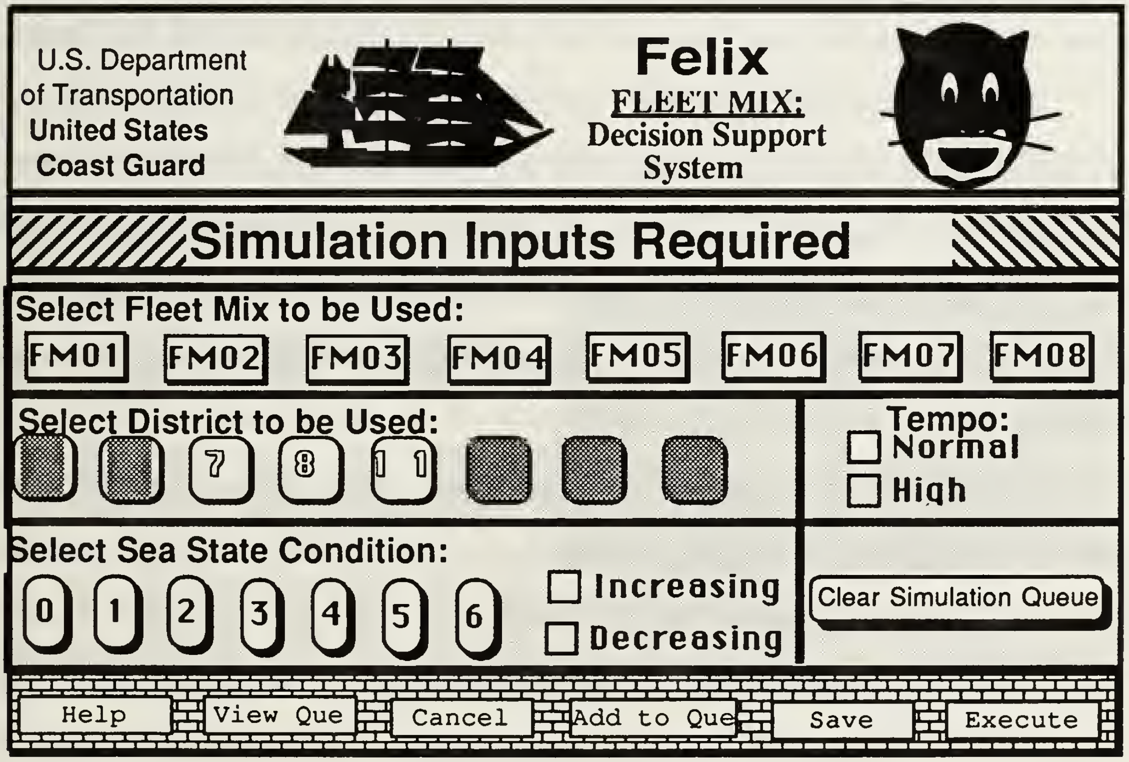

Figure 5-3 Simulation Inputs Screen.

With the simulation queue loaded, the user selects the Execute button to initiate the simulation. Felix displays the Model Base Control screen. First Nexpert is initialized. The process described in the interface section

establishes a link between the user interface and Nexpert. Next the user selects the Perform Simulation button. Program control passes to Nexpert. The first entry in the simulation queue table is read. The patrol boats for the selected fleet mix and district are positioned on an imaginary coastal ocean area. Some vessels are at sea on patrol. Other vessels are inport either in a standby condition or in a maintenance condition. A random event occurs at some location. The simulation dispatcher selects the boat that should respond to the event. The intercept course is computed for the selected patrol boat and its speed is set to maximum speed. The model computes values for measures such as the time required to intercept a vessel, and the fuel used.

The process is continued for a simulated time of one week, with random events occurring throughout the 168 hour time frame. Results for the simulation run are stored in a data table for later processing or review. The next run in the simulation queue is read in and the process repeats. The simulation continues until all Simulation Queue table inputs have been evaluated.

The user may aggregate the simulation results or return to the main menu. By selecting the Aggregate Results button, the Felix aggregation model first combines simulation results by district within a specific fleet mix alternative. For example, five simulation runs were performed on FM02 in District 7. The first level of aggregation combines the results for District 7 of FM02. The first level aggregation is continued until results are combined for each district of each fleet mix alternative. The second level of aggregation combines the district results for each fleet mix alternative. The result is a display of measures for each fleet mix alternative in the final results screen.

The summary information of one fleet mix is presented with similar information for the other fleet mix alternatives. Assessment of the final results is discussed later.

4. Typical Results

At the Main Menu, the user selects the Final Results button and a layout similar to TABLE 5-1 is displayed on the screen. The numbers are provided for demonstration purposes, and have no relationship to a real fleet. Additionally, the cost and activity measures are not computed in the current implementation. The user has the option of printing the results table or returning to the main menu.

The user can get more information about a number on the simulation results by selecting that number. Another view of the data used to develop the number is presented. For example, the user might want to look at the individual simulation results that were performed during evaluation. The user clicks on the fleet mix number with the mouse button. A scrolling list appears on the screen with all the simulation runs listed. Clicking on one of the simulation listings causes the individual results to be displayed. Figure 5-4 shows sample results for a simulation run. This completes the introductory steps in working with Felix. Detailed information can be found in the Felix User's Manual and with the Online Help system within Felix.

TABLE 5-1 SAMPLE FLEET ANALYSIS RESULTS.

Evaluation Measure	FM04	FM05	FM05	
Costs ($ millions)				
Amortized Lifecycle Cost	$600	$530	$450	
Activity (hours)				
Patrol	172,800	142,800	136,800	
Maintenance				
Defense Operations				
Performance				
SAR response time	3.6 hours	4.7 hours	4.9 hours	
Number of SAR missions	27	26	27	
Number of failed SAR missions	2	4	5	
Number of ELT missions	17	17	17	
Number of failed missions	4	6	7	
Number of ELT intercepts	8	6	6	

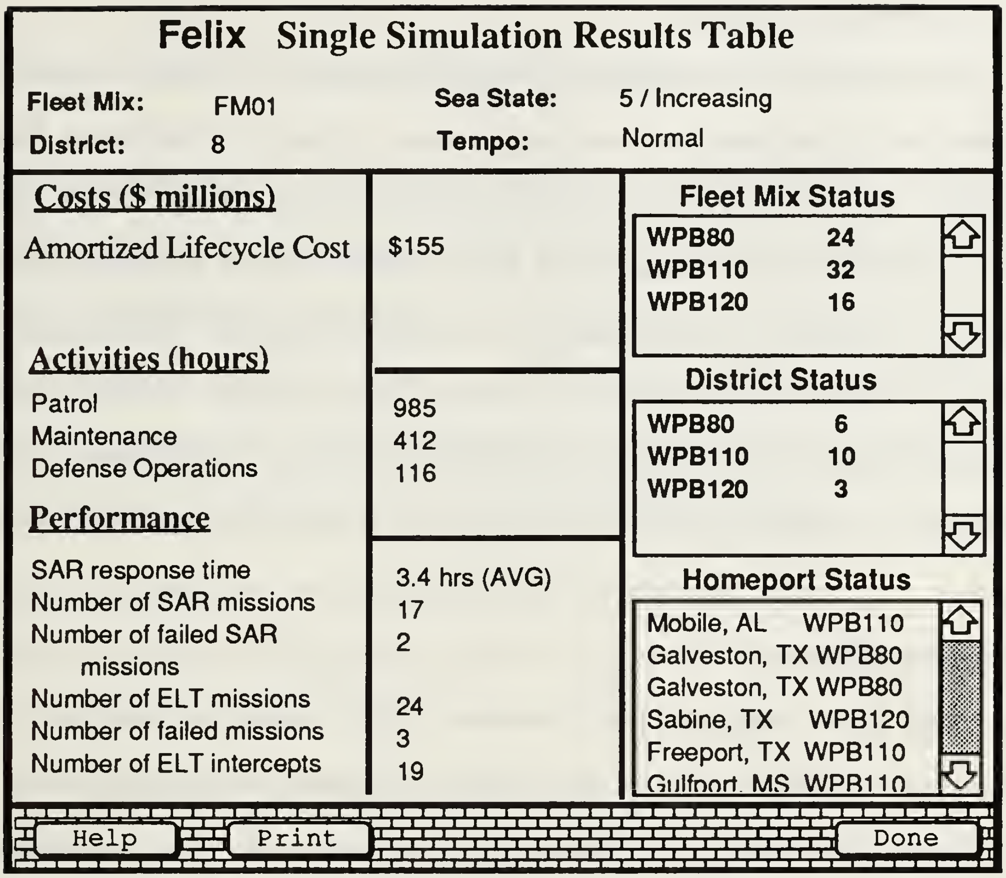

Figure 5-4 Results for a Single Simulation.

B. FLEET MIX ANALYSIS USING FELIX

The process of evaluating fleet mixes has been discussed above. The most important use of the fleet mix DSS is to compare alternative fleet mixes. This section provides a discussion of the comparison process. Decision makers will develop and use their own policies for combining the results. The next section presents some considerations for use of results. The following questions are addressed: What do the results imply about the relative quality of the fleet mix? How can the decision maker use the results of the DSS to support his selection of a fleet mix alternative?

1. Performance Analysis

The performance results are used to indicate the relative quality of the fleet mix with respect to meeting mission goals. The same basis for evaluation must be used to ensure objective comparison. Each fleet mix should have been put through the same test or series of simulation runs. TABLE 5-1 provided sample results of fleet mix analysis. The sample results indicate that fleet mix FM04 has a better performance in most categories compared to the other fleet mixes. More detail about the performance results is obtained by clicking with the mouse on the fleet mix name at the top of the column.

2. Cost Analysis

TABLE 5-1 indicates that fleet mix FM06 has the lowest cost figures compared to the other fleet mixes. The cost figures would be entered by the user for each class of ship, and this table would show the cost for the specified mix in the fleet. More detail about the costs is obtained by clicking on the number in question.

3. Activity Analysis

TABLE 5-1 indicates that fleet mix FM04 has the best activity capability for patrol boat performance and the lowest maintenance requirement. The activity characteristics for each patrol boat are entered by the user. Felix computes the combined activity hours for the fleet mix.

This chapter discussed use of the DSS to help the user evaluate and compare alternative fleet mixes. Chapter VI discusses considerations for use of the DSS, and presents recommendations for enhancement and improvement.

VI. CONCLUSIONS

Felix was designed as a prototype DSS for Coast Guard fleet mix planning. The system has been delivered to the Patrol Boat Capability Replacement Project at Coast Guard headquarters. We hope that further enhancements and modifications will be added to improve the utility of the DSS. In this chapter we present the known limitations of the system, a list of possible enhancements to the system, and issues for further research.

A. LIMITATIONS OF THE CURRENT IMPLEMENTATION

There are certain limitations on the use of the current implementation of Felix. The DSS is applicable in a narrow range of fleet mix planning. The analysis methods used do not consider all the facets of patrol boat performance. Assumptions were made for the evaluation of fleet mix performance that provide a situation different from the real world.

1. Applicability

Felix addresses only a portion of the patrol boat acquisition planning phase that is one phase of the larger fleet mix planning problem. The DSS helps during some early phases of the A-109 process, but there are five phases and milestones required for a major system acquisition. Many other aspects of the patrol boat fleet mix problem not addressed including the size of the fleet, the location of the vessels and the use of other vessels to perform SAR and ELT missions. Considerations for improving the DSS are discussed later in the chapter.

2. Analysis Methods

The evaluation process for performance is limited in the following ways:

- The simulation is performed using tables for events and tables for initial assignment of vessels. The event tables can be modified to reflect any environment desired. Initial condition tables can be modified to meet the realistic positioning of ships. It is important that the data entered in the event and initial condition tables be representative of the fleet mix problem being studied.
- The simulation occurs in a rectangular area with dimensions closely approximating each district. The modeling of the actual geography of the coastal United States was not feasible for this prototype. Similarly, islands and shoal water are not considered.
- The simulation does not consider the effects of fatigue on the crew. For example, there is no limit on the number of ELT boardings that a patrol boat could perform during a day, other than the assignment to one mission precludes an overlapping assignment to another mission.
- Use of other Coast Guard assets is not considered. The missions of other assets overlap. In reality, 40 foot boats and helicopters, along with other vessels perform SAR missions. Many other sensors, ships and aircraft coordinate their efforts at the illicit drug problem.

3. Underlying Assumptions

The following assumptions were made during the development:

- Helicopters and other Coast Guard assets will not be used to respond to any of the events generated in Felix.
- Navigational hazards will not be a factor in our analysis.
- Transit time through restricted waterways do not impose speed limitations on the cutters.
- The search part of SAR is not considered. The evaluation model directs the patrol boat to the location of the casualty.

B. ENHANCEMENTS TO THE PROTOTYPE

Felix is in the infant stage of development. There are several paths that can be taken to enhance the system via small changes to Felix. Larger

modifications and additions to the system are covered in Section C. We will discuss how the system can be enhanced in four major categories: Program, Data, Maintenance and Security.

1. Program Enhancements

Program enhancements include coding, scripting, icons, color, sound and new software applications. The following are some of the program enhancements we would like to see added to Felix.

- Provide a selection of randomly generated **event scenarios** for the simulation. Each event scenario specifies a sequence of events that will occur during the evaluation. Different scenarios would test different aspects of patrol boat performance.
- Provide a selection for the patrol boat **initial conditions** for the simulation. The initial conditions include the location, fuel remaining, hours underway and the current mission of the patrol boats within the district. Evaluation with different initial conditions will reduce the evaluation bias that might otherwise be caused with only one initial condition for the start of the simulation process.
- Allow the user to define a **simulation set**. A simulation set specifies all the simulation runs to be performed on a fleet mix. The simulation parameters for each run are also specified. By evaluating each fleet mix using the same simulation set or sets, the user is assured of a common base for comparing performance of fleet mix alternatives.
- Provide color enhancements to the user interface if justified. The capability exists with the present design, but it was not implemented.
- Provide sound enhancements to the user interface. This feature could help the user identify the type of error committed and provide extra clues about the location within the program.

2. Data Enhancements

Data enhancements provide additional information that could be used by Felix to facilitate better analysis for the decision maker. Several of the tasks accomplished in Felix use data that is entered by the user. The best method would be to gather and analyze appropriate historical data. The DSS could

use actual historical data to develop event tables or produce probability distributions that could be used in a Monte Carlo type of simulation. Examples where this method may be useful are:

- the distribution of SAR cases in the water around the major harbors, waterways and channels.
- the analysis of historical costs to be used in lifecycle cost computation. (maintenance, overhaul, mid-life maintenance, operations, etc.)
- the location of fish havens that are most likely used by fishing fleets.

3. Maintenance Enhancements

Presently, the maintenance module of the DSS has not been implemented. The design of the interface delivered with Oracle and Nexpert do not provide for maintenance through the SuperCard interface. Maintenance of the user interface is performed using SuperEdit, a program delivered with SuperCard. It comes with all the tools for designing new SuperCard applications and modifying existing applications. Additions and modifications to the database structure and design are performed using the Oracle System Stack. This is a HyperCard stack that provides the database administrator the features to manage access, tables and data. Any access to the Oracle database requires a valid user name and password. The model base is modified using Nexpert's development environment. New models can be developed entirely within Nexpert or can be called using some of Nexpert's built in features for accessing external programs.

Enhancements to the Maintenance module would include a call from the user interface to Nexpert that would completely shut down the user interface after connection. Nexpert could then be used in the development mode to do maintenance requirements. Upon completion, Nexpert would

restart Felix, establish a link and pass program control. A similar process would be required for Oracle.

4. Security Enhancements

The DSS security involves two phases. The first is controlling access to the computer through physical security. The second phase involves computer hardware or software that restricts computer use to authorized persons. The security measures implemented by software in Felix are:

- Access to the Felix DSS user interface is password controlled. Other SuperCard applications are not protected.
- Access to Oracle requires user name and password.
- Access to Nexpert Object is not restricted but, access to Nexpert is controlled by use of a hardware key that must by installed for proper use.

C. ISSUES FOR FURTHER RESEARCH

The DSS discussed in this thesis was designed to allow the developer or user to make improvements and modifications within the existing framework. Several enhancements have already been discussed. Other major areas for research include development of other models and expanding the scope of problems addressed by the system.

1. Cost Models

Cost analysis is not provided in the initial version of the prototype fleet mix DSS. Determination of cost is an important aspect of the fleet mix problem. This is an important component for further development. The costs models could be developed within Nexpert or could use Nexpert's features to call an external program like an optimization model or a spreadsheet.

2. Activity Models

Activity analysis is also an important measure in fleet mix planning. It could help the decision maker determine how many vessels are required in a district to meet a certain level of demand. The activity model could be written entirely in Nexpert or could rely on Nexpert to call an external program.

3. Performance Models

The performance models used in this research do not evaluate use of other Coast Guard assets. Further research could include development of models for use by the Navy, Army or other branches within the Coast Guard.

4. Expand to Other Aspects of the A-109 Process

The system could be augmented with features that address the other phases and milestones of the A-109 process. Possible enhancements to the system include a more elaborate cost evaluation meeting the requirements of the lifecycle cost analysis of the A-109 Circular. Further, an important enhancement would be the development of reports with justification needed for certain milestones.

D. SUMMARY

This research has built on previous fleet mix planning research. In particular, the efforts of the Coast Guard Patrol Boat Capability Replacement Branch [Ref. 8], the Coast Guard Research and Development Center [Ref. 13], and the Balance Sheet Approach to Fleet Mix Planning [Ref. 3] were used to design and develop a working prototype tool for fleet mix planning in the Coast Guard. Though the implementation of our design is partial, early feedback from the Coast Guard has been encouraging. The system

enhancements and additional research topics would add greatly to the capability of the system. The goal of the design team has been realized. We hope the project will continue, and that better fleet mix decisions will be possible as a result of using this tool.

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